DTIC FILE COPY

(1)

Technical Report 766

Validation of Psychomotor and Perceptual Predictors of Armor Officer M-1 Gunnery Performance

AD-A191 333

Elizabeth P. Smith and Scott E. Graham

Selection and Classification Technical Area
Manpower and Personnel Research Laboratory

U. S. Army

Research Institute for the Behavioral and Social Sciences

November 1987

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

WM. DARRYL HENDERSON
COL, IN
Commanding

QUALITY INSPECTED 2

Technical review by

Lawrence M. Hanser
Paul Twohig

Accession For
NTIS GRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A-1

NOTICES

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Technical Report 766	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) VALIDATION OF PSYCHOMOTOR AND PERCEPTUAL PREDICTORS OF ARMOR OFFICER M-1 GUNNERY PERFORMANCE		5. TYPE OF REPORT & PERIOD COVERED Final Report July 1985-January 1987 6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Elizabeth P. Smith and Scott E. Graham		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 20263731A791 2.3.1.H.2
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		12. REPORT DATE November 1987 13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) --		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE ---

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

--

18. SUPPLEMENTARY NOTES

--

19 KEY WORDS (Continue on reverse side if necessary and identify by block number)

Psychomotor predictors, Spatial predictors, Perceptual predictors, Computerized predictors, Gunnery prediction, Unit Conduct of Fire Trainer (UCOFT), Armor officer selection

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research examined the validity of a computerized and paper-and-pencil psychomotor and perceptual test battery for predicting M-1 gunnery performance. Using the Unit Conduct of Fire Trainer (UCOFT) M-1 simulator, 95 second lieutenants in Armor Officer Basic courses were administered the battery at the beginning of training and were tested on gunnery skills near course completion. Stepwise regression of UCOFT Composite Score resulted in a multiple R = .76, with seven variables in the model. Using (Continued)

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ARI Technical Report 766

20. Abstract (Continued)

discriminant analysis with this subset of variables, 94% of the sample were correctly classified into the top 95% and bottom 5% of the Composite Score distribution; 80% were correctly assigned to the upper and lower thirds of the distribution. Although these findings require cross-validation, they provide useful information as the first step in developing an Armor Officer preaccession screen.

Technical Report 766

Validation of Psychomotor and Perceptual Predictors of Armor Officer M-1 Gunnery Performance

Elizabeth P. Smith and Scott E. Graham

Selection and Classification Technical Area
Lawrence M. Hanser, Chief

Manpower and Personnel Research Laboratory
Newell K. Eaton, Director

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

November 1987

Army Project Number
2Q263731A791

Manpower, Personnel
and Training

FOREWORD

The Selection and Classification Technical Area (SCTA) of the Army Research Institute (ARI) currently is involved in developing and validating new paper-and-pencil and computerized instruments that measure cognitive, perceptual, and psychomotor abilities. This effort is part of research to improve the selection, classification, and utilization of enlisted personnel--Project A.

Recognizing its potential merit, the Commanding General of the U.S. Army Armor School requested in July 1985 that SCTA and the Fort Knox Field Unit undertake a joint effort to examine the predictive validity of this test battery for gunnery performance in newly commissioned Armor Officers, as measured by the Unit Conduct of Fire Trainer (UCOFT), a high-fidelity simulator. Both predictor and criterion tests are the result of technological advances that make readily accessible information heretofore difficult to obtain. This effort contributes to the SCTA mission to link soldier selection to job performance by using state-of-the-art measures. Findings were briefed to the Assistant Commandant of the U.S. Army Armor School at Fort Knox, Kentucky, in March 1987.

Edgar M. Johnson

EDGAR M. JOHNSON
Technical Director

ACKNOWLEDGMENTS

Many people helped with this research. Their contributions extended from supplying power cords and keeping the computers running to collecting and handling data to coordinating efforts. Specifically, we want to thank Jose Guerrier who left the project, but only after spending many, many hours in research planning and data collection and management. Very special thanks go to MAJ Milton Koger who arranged for and assisted with every data collection--all nights and weekends--and many other details. We also thank Jeffrey McHenry of American Institutes for Research, one of the developers of the Trial Battery test, who provided advice on the measures as well as performed the necessary transformations of the data into final form for our analysis. Finally, we acknowledge the contribution of all the Project A researchers, particularly those at Personnel Decisions Research Institute who developed the Trial Battery.

VALIDATION OF PSYCHOMOTOR AND PERCEPTUAL PREDICTORS OF ARMOR OFFICER M-1 GUNNERY PERFORMANCE

EXECUTIVE SUMMARY

Requirement:

To determine the validity of the Project A psychomotor and perceptual computer and paper-and-pencil test battery for predicting M-1 gunnery performance for newly commissioned Armor Officers.

Procedure:

Ninety-five students in Armor Officer Basic (AOB) training courses who were assigned to M-1 training between 14 January and 27 August 1986 were administered the predictor battery during their first week at AOB. Half of the battery consisted of five paper-and-pencil tests of spatial visualization (rotation and scanning), spatial orientation, and figural reasoning (induction). The other half consisted of 10 computerized tests measuring simple and choice reaction time (processing efficiency), short-term memory, psychomotor precision (two tests), perceptual speed and accuracy (two tests), two-hand coordination, number operations, and movement judgment. These tests provided a total of 32 different scores. Data analyses were performed using the scores individually and combined into six composites. The Nelson-Denny Reading Test, a measure of general verbal ability, taken as part of regular course procedures, was included as an additional predictor. Approximately 2 to 3 weeks before completion of the course, subjects were tested on tank gunnery performance on the Unit Conduct of Fire Trainer (UCOFT), a high-fidelity simulator. The UCOFT provided scores for number of hits and opening times over three sets of exercises under different conditions and for tracking error from a fourth exercise. A UCOFT Composite Score combining all three variables was used as the major criterion for analysis.

Findings:

The predictor battery exhibits substantial criterion validity. Stepwise multiple regression of the UCOFT Composite Score on the individual predictor variables resulted in a regression model containing seven variables from five tests with a multiple correlation coefficient ($\underline{R}$) equal to .76. This indicates that the regression model can account for more than half (53%) of the variance in criterion scores. Nelson-Denny score did not enter into the equation. By itself, Nelson-Denny score, as a measure of general ability, can explain only 4% of the criterion variance. This variance is subsumed by that explained by the regression model. Subsequent discriminant analysis with the reduced set of variables correctly classified 94% of the cases as successful (upper 95%) or unsuccessful (lower 5%), with most errors found for marginal cases. Similarly, lower, but still ample, validity was found by regressing (a) composite scores based on subsets of the exercises on the individual

predictor variables and (b) total Composite Score on six predictor composites formulated on the basis of factor analysis.

Utilization of Findings:

The research results demonstrate that a measure of general ability has little validity for predicting gunnery performance as measured here, but that the battery of predictors taken from Project A has a high level of validity for this small sample. These findings, which require cross-validation with additional samples of subjects, can be used by the Armor School to develop an Armor Officer preaccession screen using these or similar predictor measures, and to select tank gunners in general. Moreover, the results show that prediction based on general ability can be incremented by using perceptual and psychomotor tests for certain kinds of performance.

VALIDATION OF PSYCHOMOTOR AND PERCEPTUAL PREDICTORS OF ARMOR OFFICER M-1 GUNNERY PERFORMANCE

CONTENTS

LIST OF TABLES

CONTENTS (Continued)

LIST OF FIGURES

VALIDATION OF PSYCHOMOTOR AND PERCEPTUAL PREDICTORS OF ARMOR OFFICER M-1 GUNNERY PERFORMANCE

INTRODUCTION

The issue of selection and assignment of the best individuals to jobs within the military is an ongoing problem. Researchers constantly are working to improve methods available for maximizing person-to-job matches. Although problems occur at all levels, both for enlisted and officers, the greatest amount of attention tends to focus on entry-level classification. At the present time, the Army is involved in an extensive research program to improve procedures for the selection and classification of enlisted personnel, Project A (Eaton, Goer, Harris, & Zook, 1984). One of the objectives of Project A is to expand the range of tools available to enable measurement of cognitive, perceptual and psychomotor abilities and temperament variables within individuals and to determine how these abilities relate to success. Work in this area has resulted in a Trial Battery of both pencil-and-paper and computerized tests to predict job performance among enlisted personnel. Data to validate the Trial Battery against a number of job performance criteria (hands-on tests, peer and supervisory ratings, and job knowledge tests) were collected during the Project A Concurrent Validation (CV) and are currently undergoing analyses. Preliminary analyses indicate that the Project A Trial Battery provides incremental validity over that of ASVAB alone (Campbell, 1986) in predicting enlisted performance.

Although the Trial Battery was created with the general purpose of selection and classification of enlisted personnel, it may have potential for additional applications and solution of other more specific problems. Specifically, the present research reports on efforts to examine the validity of some of the Trial Battery as predictors of gunnery performance among new Armor officers. This work was undertaken at the request of the Commanding General of the U.S. Army Armor School at Fort Knox, Kentucky.

The Army Problem

Division 86 Tank Platoons contain four tanks, one of which is commanded by the platoon leader (Plt Ldr). The Plt Ldr's battlefield responsibilities include controlling the movement of the platoon, employing all available fires, including the call for indirect and the distribution of platoon fires, and keeping the company commander informed of the situation. Equally important, the Plt Ldr must effectively fight his tank, as his tank represents one-quarter of the platoon firepower. To be successful, the Plt Ldr must lead and execute by example, using the leadership concept of "follow me and do as I do" (The Division 86 Tank Platoon, 1986).

Gaining the respect of platoon members is by no means automatic, but a function of how well the Plt Ldr performs. Given the armor combat mission to put "steel on target," execution of gunnery skills is particularly important. The acceptance of the Plt Ldr and ultimately the success of the platoon on the battlefield is therefore determined by the Plt Ldr's ability to demonstrate at least minimal proficiency in gunnery. In addition, gunnery performance, particularly poor performance, can weigh heavily in an Officer's Efficiency Rating (OER) and, hence, his career.

Plt Ldr training is given in the Armor Officer Basic (AOB) course to second lieutenants (2LT) who have just entered the Army from the U.S. Military Academy, university Reserve Officer Training Corps (ROTC) or who have been promoted from enlisted ranks through Officer's Candidate School (OCS). The AOB course taught by the Armor School, Fort Knox, KY, contains approximately 4 months of training, less than half of which is actually on tanks or dealing with gunnery. By comparison, the two enlisted tank commanders (TC) in the platoon typically have more than four years of armor experience, with the platoon sergeant having eight to ten years experience. In practice, the new Plt Ldr receives the majority of his tank training from his platoon sergeant and company commander after taking command of his first platoon.

The basic problem addressed by this research concerns the small percentage of AOB graduates who are so uncoordinated that they are unlikely to become successful Plt Ldrs. Like all other tanks in the battalion, the Plt Ldr is expected to qualify his tank on the tank table exercises. Certain novice Plt Ldrs with limited psychomotor, perceptual, and spatial skills have such poor gunnery skills that tank qualification is virtually impossible. Similarly, certain Plt Ldrs are so uncoordinated that they never develop acceptable gunnery skills regardless of the amount of training.

Deficiency in psychomotor, perceptual, and spatial skills related to gunnery performance may be detrimental to Plt Ldr's effectiveness for two reasons. First, those lacking needed skills fail to gain the respect of their platoon because they cannot lead by example. Lack of crew confidence then spreads to other areas not related to gunnery, even when the Plt Ldr is effective in those areas. Second, a Plt Ldr who cannot fight his tank may cause battlefield casualties for himself and the entire platoon. These same officers, however, may well be intelligent, motivated, and have a successful Army career in a non-combat arms branch. It would be valuable for both the Army and the individual if a diagnostic tool could direct individuals early-on into career fields to which they are better suited.

One problem that has occurred in attempts to predict armor gunnery performance is selection of the appropriate criterion. Ideally, predictor tests are validated against on-the-job performance. For armor gunnery, the tendency has been to use Tank Table VIII qualification scores. Live-fire scores, however, may not always be most appropriate. Problems affecting the reliability of these scores, e.g., varying weather and equipment conditions, make questionable the comparison of scores across days, ranges, and units. Tank table exercises, in addition, measure total crew performance. This is inappropriate if one is interested in the performance of an individual crewman. The use of Tank Table VIII as a valid measure of individual performance is also suspect in that the primary goal of Tank Table VIII is to qualify as many tanks as possible. Every effort is therefore made by the unit to minimize the effects of individual crew deficiencies. While some of the live-fire criterion problems can be eliminated by running well-controlled gunnery exercises specifically for validation research, ammunition costs and support requirements usually

prohibit such an effort. In addition, live-fire exercises designed to evaluate gunnery skills of minimally trained crewmen (such as in the present research) pose safety problems.

High-fidelity tank gunnery simulators such as the Unit Conduct of Fire Trainer (UCOFT) are being considered as alternatives to live-fire testing as performance measures. The M-1 UCOFT is a whole-task gunnery trainer which simulates the tank optics system with computer-generated imagery. The TC and gunner controls are virtually identical to those in the actual tank, making the UCOFT analogous to flight simulators used in military and commercial training. The UCOFT can measure performance on a full range of target engagement tasks: target acquisition, laying the gun, and the issuing of fire commands. Device-mediated tests with the UCOFT offer certain advantages over other hands-on performance tests. These plusses include standardized administration and scoring and the capability of inexpensively building longer tests with varied target conditions. Another advantage of the UCOFT is that it trains and/or tests degraded mode gunnery techniques. For example, the computer can simulate failure of various components in the fire control system, e.g., the laser range finder.

Another problem in predicting gunnery performance is determining the best predictive measures. Although higher general ability people may perform better in Table VIII exercises (Scribner, Smith, & Baldwin, 1986), among new officers with fairly equal ability, other measures are needed to distinguish unsuccessful from successful gunners. In this research, the predictors were not developed specifically to predict gunnery performance. However, the psychomotor and perceptual abilities they are intended to measure do have face validity for gunnery performance. That is, one can easily agree that these types of abilities appear to be necessary for successful performance.

METHOD

Sample

Subjects were 2LTs who participated in the Armor Officers Basic Training (AOB) courses in session between 14 January and 27 August 1986 and who were assigned to M-1 tank training. A total of 6 classes were tested and classes ranged from 8 to 24 officers each. Although 112 subjects took the predictor battery, criterion data were available for only 95 of these. This reduction in subjects was due to such things as failure to complete the course, scheduling difficulties, and loss of data due to electrical failure. In addition, portions of the criterion data unavoidably were lost on an individual basis in the process of data transfer.

Description of the Instruments

Table 1 is a summary of the battery of instruments used in this research. The names of the scores obtained from each are noted. More thorough descriptions of the tests are presented below. The Project A Trial Battery contained an additional spatial test, Assembling Objects. This test was eliminated from the present research because of time limitations.

Table 1

Summary of Predictor Measures

Test Name	Construct	Number of Items	Time Limit	Score	Reliability
Nelson-Denny Reading Test	General Verbal Ability	136	—	No. Correct	.91[a]
Part 1: Vocabulary		100	15 min.		
Part 2: Comprehension		136	20 min.		
Project A Tests Paper and Pencil Tests					
Reasoning Test	Induction	30	12 min.	No. correct	.87[b]
Object Rotation Test	Spatial Visualization: Rotation	90	7.5 min.	No. correct	.99
Orientation Test	Spatial Orientation	24	10 min.	No. correct	.89
Maze Test	Spatial Visualization: Scanning	24	5.5 min.	No. correct	.96
Map Test	Spatial Orientation	20	12 min.	No. correct	.90
Computerized Tests					
Simple Reaction Time	Processing Efficiency	15	—	Decision time mean Movement time mean % correct	.88 — .46
Choice Reaction Time	Processing Efficiency	30	—	Decision time mean Movement time mean % correct	.97 — .57
Memory Test	Short Term Memory	36	—	Decision time mean Movement time mean % correct	.96 — .60
Target Tracking 1	Psychomotor Precision	18	—	Mean log (distance + 1)	.98
Perceptual Speed and Accuracy	Perceptual speed and accuracy	36	—	Decision time mean Movement time mean % correct	.94 — .65
Target Tracking 2	Two-hand coordination	18	—	Mean log (distance + 1)	.98

Table 1 (continued)

Summary of Predictor Measures

Test Name	Construct	Number of Items	Time Limit	Score	Reliability
Number Memory Test	Number Operations	28	—	Final response time mean	.88
				Input response time mean	.95
				Pooled operation mean	.93[c]
				% correct	.59
Cannon Shoot	Movement judgment	36	—	Absolute time discrepancy Mean	.65
				Mean log (distance ÷ 1) error	-
				% hits	-
Target Identification	Perceptual speed and accuracy	36	—	Decision time mean	.97
				Movement time mean	-
				% correct	.62
Target Shoot Test	Psychomotor precision	30	—	Mean log (distance ÷ 1) error	.74
				Mean time to fire	.85
				% hits	-

[a] Median alternative forms reliability obtained from test manual.

[b] Split-half (odd-even) reliability with Spearman-Brown Correction for length based on Project A Concurrent Validation (CV) data ($\underline{n}$ = 9332 to 9345).

[c] Coefficient alpha reliability based on CV data.

Nelson-Denny Reading Test

As a regular part of the AOB course, students are given the Nelson-Denny Reading Test. Reading tests such as the Nelson-Denny have been shown to correlate very highly with measures of general ability or trainability. For example, the Adult Basic Literacy Examination (ABLE) has been found to correlate .85 with the General Technical (GT) composite obtained from the ASVAB (F.C. Grafton, personal communication, January 6, 1987). In this research, we used total score combining the Vocabulary and Comprehension subtests taken during the AOB course as a measure of general ability.

Paper-and-Pencil Tests

Reasoning. This instrument measures figural reasoning, or the ability to determine the underlying principles governing relationships among a series of figures. Each item consists of four figures in a series. The examinee must decide what pattern or rule governs their relationship and select the figure that completes the series from five alternatives. This test is expected to contribute to prediction of performance in such areas as detecting and identifying targets, troubleshooting and repair work, and analysis of intelligence data (Peterson, 1987).

Object Rotation. This test measures spatial visualization/rotation involving two-dimensional figures. This is the ability mentally to rotate figures or to manipulate or restructure their component parts. In this test, examinees are presented with two test objects (stimulus figures). For each object there are five test items. These items consist of the same figure as the object only flipped over or rotated in one direction or another. The examinee must indicate whether the item figure is the "same" (rotated) or "not same" (flipped). Development of the test was based on the expectation that it would predict success in such areas as map drawing and use and mechanical or construction operations (Peterson, 1987).

Orientation. This test measures the ability to maintain one's perspective or bearing with respect to some object when it and its component parts have been rotated. In this test, each item presents a picture within a frame, but the picture is in a non-upright position. At the bottom of the frame, there is a circle with a dot inside. The examinee mentally must rotate the frame so that it is lined up correctly with the picture. Then, because the dot within the circle also rotates, he/she must decide the placement of the dot (i.e., how the dot should look in relation to the circle). Five response choices are provided. This test is expected to predict success in activities involving maintaining position relative to environmental landmarks or location under frequent directional changes (Peterson, 1987).

Maze. This instrument measures a different aspect of spatial visualization, spatial scanning. This is the ability to scan or survey a complex field visually and to identify a particular pattern, configuration, or pathway within the field. The test items are rectangular mazes with four labeled entrances (A to D) and several exits. Only one entrance leads to

an exit and the examinee must decide which one it is. This test is likely to predict success in using maps in the field, in electronic operations, and in air traffic controlling (Peterson, 1987).

Map. This is also a test of spatial orientation. It was designed to test the ability to establish and maintain one's bearing or to reorient oneself in relation to environmental features or landmarks (Peterson, 1987). The test consists of presentation of two different maps with landmarks (e.g., mess hall, campsite, lake). No indication of compass directions are indicated on the maps. Ten test items refer to each map. Each item provides information about direction (e.g., "the forest is north of the campsite"). The subject must use to this information to determine what direction to travel to reach another landmark.

Computer Tests

Overall. The computer tests required a response pedestal specially designed for this test battery. The pedestal is pictured in Figure 1. It has two joysticks to enable subjects to select which hand they prefer to use, horizontal and vertical slide controls, three response buttons (BLUE, WHITE, and YELLOW), and two RED buttons. Four green "HOME" buttons serve the special purposes of a) controlling the location of subjects hands during stimulus presentation, b) controlling the onset of test items, and c) enabling assessment of both decision and movement components of reaction time (Peterson, 1987).

As indicated in Table 1, Simple and Choice Reaction Time, Memory, Perceptual Speed and Accuracy, and Target Identification yield decision time means (time from onset of stimulus to release of HOME button) and movement time means (time from release of HOME to hitting response button) and percent correct scores. The first two scores are trimmed of highest and lowest responses because subtle events such as guessing time of next onset, stretching, yawning, etc., can produce extreme scores (Peterson, 1986). Mean log (distance + 1) error scores for Target Tracking 1 and 2 and Target Shoot are based on the distance from the center of the crosshairs to the center of the target box. For the tracking tests, the distance is measured repeatedly -- approximately 500 times per trial. The mean of these distances is used for the per-trial scores which, in turn, are averaged to yield one mean score. For Target Shoot only one distance measure is taken per trial (at the time of firing). Cannon Shoot Absolute Time Discrepancy Mean is the average of the absolute value of the difference (discrepancy) between the time the subject fires and the optimal firing time for making a direct hit. Number Memory scores present mean scores for processing each step, i.e.. time until button is pushed to go on to the next step (Input Response Time), completing all arithmetic operations (Pooled Operations Time), and deciding if the answer given is correct (Final Response Time).[1]

----

[1]Explanations for the scores presented here were provided by J. McHenry (personal communication, January 21, 1987).

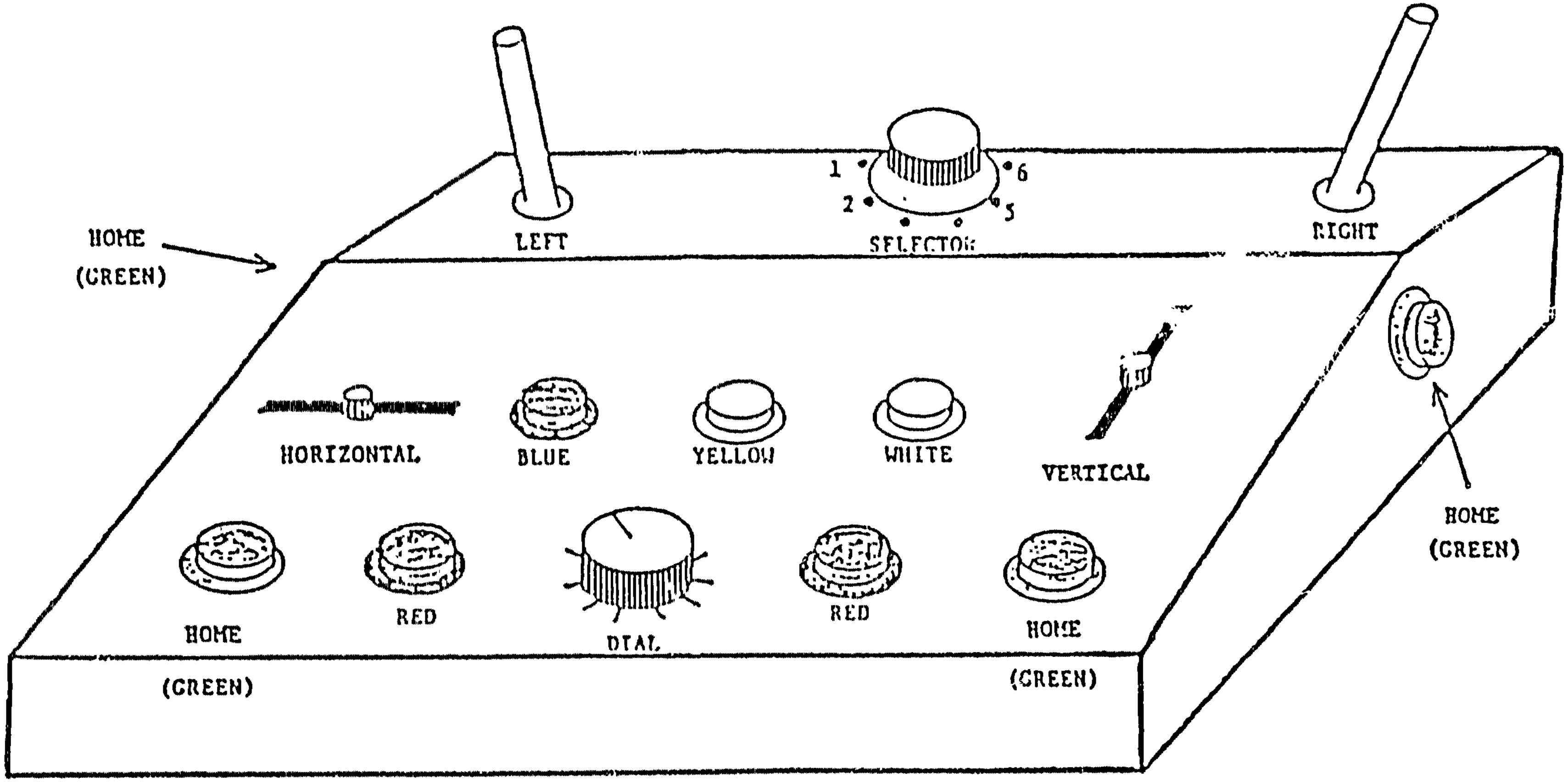

Figure 1. Response pedestal for computerized tests.

Simple Reaction Time. The first test is a measure of processing efficiency. The first five items are practice items to enable the subject to get accustomed to the equipment and are not scored. Subjects start with both hands on the four HOME buttons (ready position). Each item consists of presentation of the stimulus word "YELLOW". As soon as the subject perceives the word, he must press the YELLOW response button.

Choice Reaction Time. The second measure of processing efficiency requires a choice response. Instead of the stimulus "YELLOW", the stimulus is either "BLUE" (7 items) or "WHITE" (8 items). When it appears, the subject must release the HOME button and press the correct color button. All items are scored.

Memory. This tests measures "the rate at which one observes, searches, and recalls information contained in short-term memory (Peterson, 1986, p. 5-17)". Subject begins with hands in ready position. The item stimuli consist of 1 to 5 letters which are displayed for .5 or 1 second. After 2.5 or 3 seconds delay, a probe item (letter) appears. Subject must decide if the probe appeared in the original stimulus set and press the WHITE (yes) or BLUE (no) button.

Target Tracking 1. This test measures control precision or "ability to make fine, highly controlled movements to adjust a machine control mechanism in response to stimulus whose speed and direction of movement are perfectly predictable (Peterson, 1987, p. 5-39)." This pursuit tracking task uses a joystick. For each item, a path of horizontal and vertical line segments is presented. There is a target box with centered crosshairs at the start of the path. This target moves along the path at a constant speed. The subject is required to keep the crosshairs centered on target at all times. Across trials there is variation in crosshairs and target speeds, length of the path, number of segments making up the path.

Perceptual Speed & Accuracy. This test measures ability to compare simultaneously presented stimuli rapidly. The pairs of item stimuli consist of 2, 5 or 9 characters presented as a series of letters, numbers, symbols, or real words. The subject must make a determination of "same" (WHITE button) or "different" (BLUE button), release the HOME button, and press the correct color button. Items disappear from the screen as soon as HOME buttons are released to prevent overlap of decision time with movement time (Peterson, 1987).

Target Tracking 2. This is another pursuit tracking test, but it is designed to measure multilimb (two-handed) coordination. Instead of a joystick, the subject controls movement of the crosshairs using the vertical and horizontal slides.

Number Memory. This tests the ability to do simple arithmetic operations quickly and accurately using one's memory. For each item, several steps are presented. The subject is first given a number. This disappears when he presses a button to receive the next part of the problem which is another number with an operation sign (e.g., +, -). He continues this procedure until an answer is presented. Then the subject must indi-

cate if the solution is correct (WHITE) or not (BLUE) and press the right button. Items vary in the number of parts or steps involved and in the time delay between offset-onset of each part.

Cannon Shoot. This test measures movement judgment, or the ability to determine when to fire at a moving target so that the target is hit when it crosses the cannon's line of fire. Each trial begins with presentation of a cannon followed shortly by appearance of a target moving at constant speed and direction. The subject must push a RED response button so that the lines of the shell and target intersect. Across trials, there is variation in the location of the cannon, speed and direction of the target, angle of target to cannon, distance from cannon to impact point and from fire point to impact point.

Target Identification. This is another measure of perceptual speed and accuracy using meaningful figural representations rather than numbers, letters, symbols, or words. In this test, each item consists of a target figure (representing simple renditions of tanks and other tracked vehicles, helicopters, fixed-wing aircraft) at the top of the screen and three stimulus figures (labeled BLUE, YELLOW, and WHITE), one of which matches the target object at the bottom of the screen. The drawings used are modeled on the standard flash cards used in training soldiers to recognize vehicles, etc. The subject must identify the matching stimulus and press the correct color button. Targets vary from the stimuli in size, angle of rotation, and/or direction (face left or right).

Target Shoot. This measures psychomotor precision. For each trial, the target box and crosshairs appear at different points on the screen. The target moves about unpredictably, changing both speed and direction. Using the joystick, the subject must center the crosshairs on the target and press a RED button to "fire" at the target.

UCOFT Criterion Test

A UCOFT test was designed to assess gunnery skills necessary for engaging targets with the main gun from the TC's station and piloted with several subjects. During a target engagement, the TC must identify the target and make a gross lay of the main gun such that the target is within the 3 power field of the view of the gunner's primary sight. In an attempt to measure these skills, an exercise requiring the gross lay of the main gun was included in the pilot UCOFT test. This exercise required the TC to scan the simulated battlefield through the UCOFT's forward unity periscope, and lay the main gun near the target. Pilot subjects with minimal UCOFT experience had so much difficulty detecting the targets, however, that the exercise was removed from the final test. In addition, while target acquisition is a critical aspect of gunnery, acquisition of computer-generated targets on the UCOFT may be unrelated to performance in the field (Rapkoch & Robinson, 1986).

The test shown in Table 2 included a practice exercise, a tracking exercise, and three gunnery exercises. The UCOFT commander training exercises selected for the test were approved by the Weapons Systems

Table 2

UCOFT Test Engagement Conditions

	UCOFT Exercise Number	Number of Engagements	Own Vehicle	Target	Fire Control Malfunction	Notes
Practice	213110	5	Stationary	Short-Range/ Moving	None	Not Scored
Tracking	111561	5	Stationary	Short-Range/ Moving	None	Target Tracked for 30 seconds
Exercise A	223120	10	Stationary	Long-Range/ Moving	None	
Exercise B	224110 & 224111	10	Moving	Long-Range/ Stationary	None	
Exercise C	213210	10	Stationary	Short-Range/ Moving	Stabil- ization System	Manual Lead Must Be Applied

Department, USAARMC. Performance on similar UCOFT tests designed for other research has been found to be reliable with test-retest reliability coefficients exceeding .80 (Graham, 1986)

The procedures used for testing differed in several ways from standard UCOFT training procedures. All of the test engagements were fired from a 3-man crew configuration, i.e., there was no gunner. As is normally the case, the Instructor/Operator (I/O) functioned as loader and driver. All engagements were also fired with the main gun, with only one sabot round allowed per target. This stipulation eliminated the need for switching the gun select and ammo select switches located in the gunner's station, and hence the need for a gunner. The one round per target limitation also helped ensure that the TC was prepared for subsequent targets. In addition, reticle aim and timing data are reported on the UCOFT only for the last round fired. Limiting each target to one round, therefore helped standardize performance data across subjects and engagements.

The test also included procedures designed to minimize the effects of target acquisition, as previous research (Graham, 1986) has found acquisition times greatly influence UCOFT performance. The purpose of the UCOFT test was not to measure the ability to discriminate computer-generated images. Variations in target acquisition times were minimized by having the I/O talk the TC onto a reference point before each target appeared.

The reticle was positioned such that the target, e.g., a T-72 tank, always emerged within the 10 power field of view of the gunner's primary sight (GPS) extension. Magnification was kept in 10 power.

The first exercise for record was a UCOFT "Acquisition and Manipulation" exercise used to assess smooth tracking ability. The exercise included five moving targets for which the TC had to lase, fire, and then track the target for approximately 30 seconds. Tracking performance was evaluated using two measures. The first measure was Percent Time on Target, measured from when the TC fired until the target disappeared. This measure was taken from the UCOFT "Situation Monitor" report printed at the end of each exercise. The UCOFT also measures azimuth and elevation deviations from center mass of target reported in mils every second. From these data a Root Mean Square error from center mass (the hypotenuse) was calculated using the equation; $RMS = \sqrt{AZ^2 + EL^2}$, where AZ and EL are azimuth and elevation deviation scores. For the five targets, the RMS error was computed for the last 15 secs of each track. Because the TCs fired at different times, only the last 15 secs of each track was tabulated to standardize the measure across targets and subjects. RMS error is more similar to tracking measures in the predictor tests amd provides better information than Percent Time on Target. A high inverse correlation was expected between the two UCOFT tracking measures. Thus, only RMS error was used in the analyses.

Three whole task gunnery exercises were then presented with ten engagements each. As seen in Table 1, the first of these exercises (Exercise A) required the TC to fire at single long range moving targets from a stationary tank. The defensive engagements required the TC to give a fire command including a direction for the driver to move out. During the simulated tank movement, the TC had to engage the tank stabilization system by depressing the palm switches on the control handles. As the movement stopped, the TC moved the reticle onto the target, began tracking, lased, continued to track, and pulled the trigger. Good gunnery performance also required that the TC evaluate whether the range returned was accurate or not, and the monitoring of the multiple laser return, malfunction, and ready-to-fire symbols.

The next set of engagements (Exercise B) required the TC to fire at long range stationary targets from a moving tank. On moving own-tank engagements, the simulated tank made several turns as it moved up and down hills towards the targets spaced up to a minute and a half apart. Because the tank would sometimes make a turn only seconds before the target appeared, talking the TC onto the reference point was more difficult than on the own-tank stationary engagements. To aid this process, the TC were instructed to release the palm switches after engaging each target which disengaged the stabilization system and ensured the gun tube remained over the front of the tank.

The last set of engagements (Exercise C) simulated failure of the stabilization system, including the auto lead mechanism. This exercise required the TC manually to lead the short range moving targets as a function of target speed and distance.

The dependent measures gathered from the three whole-task exercises were number of hits and opening times. Number of hits was simply the number of targets killed out of the ten presented for each of the three exercises. This measure was actually first round hits as only one round was fired at each target. Mean opening times were computed separately for the three exercises as well. Opening time measures the amount of time from when the target appears to when the first round is fired. For engagements in which no rounds were fired, an opening time of 24 seconds was entered, the maximum UCOFT opening time. Although there are certain situations in battle where it is advantageous not to fire, failure to fire at UCOFT targets is, however, by definition, an error. Assigning the maximum opening time when the TC did not fire gave a poor score for poor performance.

We calculated a speed/accuracy score for the three exercises individually and over all combined by subtracting the standardized opening time score from the standardized hit score. We also calculated an overall Composite Score combining the six standardized hits and opening times scores with the standardized RMS error score from the tracking exercise. The Composite Score was our primary criterion measure.

Procedures

Two separate testing sessions were required for administration of the predictors and the criterion UCOFT testing. Subjects took the predictor battery during their first week of training. Thus there were six sessions of approximately 3 - 3 1/2 hours. UCOFT testing was accomplished approximately 2-3 weeks before course completion. Since only 3 subjects could be tested during each session, there were approximately 15-18 one hour sessions.

Predictor Battery. The researchers advised all subjects of the purposes of the test and confidentiality of the results in a single large group. Then we randomly split subjects into two groups. One group took the computer battery first, the other took the pencil-and-paper tests first. The order of tests within groups was standardized across subjects and was as indicated in Table 1. All pencil-and-paper tests were timed. Subjects read the instructions and were given the opportunity to ask questions. The computerized tests were self-administered on Seequa Chameleon computers using the special response pedestal. All instructions were provided on the computer. A researcher monitored testing and was available to answer questions. The Nelson-Denny Test was administered at the Armor School separately during regular course time.

Criterion Testing. The UCOFT test required each soldier to be tested individually for one hour. Operation of the UCOFT and administration of the test were performed by seven UCOFT I/O provided by the Weapons System Department, USAARMC. ARI personnel helped monitor testing. The session began with a general briefing on the project's purpose and a reminder that data gathered would not become part of the soldier's record.

The I/O explained the UCOFT procedures during the standard UCOFT introductory exercise (11121) and practice exercise. In the introductory exercise, the subjects (hereafter referred to as the TC) were shown each of the UCOFT graphic targets (tank, truck, armored personnel carrier, and helicopter). The TC were shown center mass of each target, i.e., the location of a perfect shot, and were told to range with the laser range finder (LRF) and fire. No troop or machine gun targets were included in the test. During the introduction, the I/Os reminded the TCs of the locations of the GPS magnification, gun select, fire control mode, and turret power switches, as manipulation of these switches were required during the exercises.

The I/Os also told the TC that he must set the gun select switch to safe and the magnification to 3 power at the beginning of each exercise. After each exercise began, he had to set-up for a 3-man crew, i.e., switch to main gun and 10 power. He was also told that if the tank was exposed too long during . defensive engagement, the sight would go black to simulate being killed. At that time he had to reset the gun select switch to main gun. If a TC forgot to do this during the exercise, the I/O reminded them before the next target appeared.

Following opening instructions, there was a practice exercise (half of exercise 213110) containing five short range (<1500 meters) moving targets which were fired at from a defensive position, i.e., own tank stationary. For defensive engagements, the TC was told that his tank was turret-down behind a berm and that he must command the tank be moved to a hull-down position before firing. During practice, if he failed to give the proper command when the target was identified, the TC was reminded that the proper 3-man crew main gun fire command was "Load sabot-Driver move out-On the way (when round was fired)-Driver move back." If the TC failed to give the proper fire command during the exercises, the I/O entered the information by hitting the ID ERROR key, another deviation from standard UCOFT procedures.

As indicated in the test description section, I/O talked TC onto a reference point before each target to minimize variations in target acquisition times. For example, the I/O would tell the TC to "Traverse left," until he was near the target azimuth location indicated on the I/O's screen. The I/O would then say "Steady on - place the reticle on the upper left corner of the house." For some soldiers tested, ARI personnel talked the TC onto the targets rather than the I/O.

The I/O were instructed to help the TC only during the introduction and practice exercise, as this was a gunnery test and not training. During the practice, however, the TC were repeatedly asked if they had any questions. Preventing test administrators who normally serve as Army trainers from providing help to soldiers is a persistent problem. ARI personnel monitored the I/O to keep the coaching to a minimum during the actual testing.

Analyses

General descriptive statistics (means and standard deviations) were calculated for predictor and criterion scores. We ran separate factor analyses on the criterion and predictor scores for data reduction purposes, i.e., to assist, in making informed decisions about creating composite scores. We computed correlations between the Nelson-Denny Score and criterion score to compare the predictive validity of Nelson-Denny alone to that of our full battery. Multiple regression analyses were performed on the criterion composite for sets of (1) individual predictor variables, (2) predictor composites based on our factor analysis, and (3) predictor composites based on preliminary Project A factor analysis of the CV data, in order to determine the amount of criterion variance accounted for by the predictor variables. Results of the regressions were used to select subsets of variables with maximal relationship to the criterion which were then entered into discriminant analyses. For these analyses, we divided subjects into successful (top 95% of scores) and unsuccessful (bottom 5% of scores) groups based on their UCOFT Composite Score. The discriminant analyses then enabled us to determine how accurately membership in each group could be predicted from our predictor battery test scores. Additional regression analyses for Exercises A and C combined and Exercise B alone were performed to examine potential differences in predictive validity.

RESULTS

Means and standard deviations, along with minimum and maximum values, for both predictor and criterion variables are presented in Table 3. The UCOFT Composite Score combines standardized hits, opening times, and tracking scores. It was calculated on the basis of a principle components factor analysis with varimax rotation which resulted in a one-factor solution. Factor loadings are given in Table 4. Note that hits have negative loadings. Because longer opening times and greater tracking error reflect lesser ability, however, in forming the composite, these scores were negatively unit-weighted and hits were positively unit-weighted. Thus, Composite Score equals the sum of the hits minus the sum of the opening times minus tracking RMS error. When scores were rounded to the nearest whole number, they formed a nearly normal distribution.

We first performed stepwise regression analysis of the Composite Score on the individual predictor variables. All independent variables were standardized to a mean of 50 and a standard deviation of 10. In order to include as many subjects as possible, missing values were replaced with the sample means. The results of the regression are summarized in Table 5. After nine steps, seven variables from five predictor tests met the requirement that their partial $\underline{F}$ be significant at $\underline{p} < .05$ to remain in the equation. The multiple correlation ($\underline{R}$) equals .76, indicating that this regression model can account for 58% of the variance in Composite Score. The strunken or adjusted $\underline{R}$ was estimated to be .74, because the variables were standardized, they can be ranked according to the absolute values of the $\underline{B}$ coefficients. Thus, Number Memory Input Response Time Mean has the greatest

TABLE 3

Means, Standard Deviations, Minimum and Maximum Values for Predictor and Criterion Sc· ·s.

Variable.	N	Mean[a]	Sd	Minimum	Maximum
Predictors					
Simple Reaction Time					
Percent Correct	95	99.1	4.4	70.0	100.0
Mean Decision Time	94	27.9	4.2	21.0	41.3
Mean Movement Time	94	21.1	39.1	13.4	35.3
Choice Reaction Time					
Percent Correct	95	99.1	2.4	83.3	100.0
Decision Time Mean	95	38.7	5.3	26.2	54.5
Movement Time Mean	95	22.3	3.6	13.0	32.5
Short Term Memory					
Percent Correct	95	91.0	6.8	66.7	100.0
Decision Time Mean	95	77.5	19.4	40.8	140.3
Movement Time Mean	95	35.2	12.2	18.7	87.3
Tracking 1					
Mean Log (Dist + 1) Error	95	2.8	0.4	2.2	4.0
Perceptual Speed and Accuracy					
Percent Correct	95	90.4	8.0	55.6	100.0
Decision Time Mean	95	226.2	54.2	41.6	338.5
Movement Time Mean	95	31.1	7.2	19.3	60.5
Tracking 2					
Mean Log (Dist + 1) Error	95	3.5	0.4	2.5	5.0
Number Memory					
Percent Correct	95	92.4	7.3	67.9	100.0
Final Response Time Mean	95	129.0	28.8	80.1	224.2
Pooled Operations Time Mean	91	160.8	53.1	63.5	317.4
Input Response Time Mean	95	126.4	41.4	57.2	287.8
Cannon Shoot					
Percent Hits	95	57.1	8.1	33.3	83.0
Absolute Time Discrepancy Mean	95	40.8	5.8	23.8	53.0
Mean Log (Dist + 1) Error	95	1.9	0.1	1.5	2.0
Target Identification					
Percent Correct	95	92.0	8.9	25.0	100.0
Decision Time Mean	94	169.8	53.5	50.9	486.3
Movement Time Mean	94	33.8	8.2	19.8	67.2
Target Shoot					
Percent Hits	95	57.2	12.2	23.3	83.0
Mean Time to Fire	95	245.3	53.4	152.7	394.3
Mean Log (Dist + 1) Error	95	2.1	0.2	1.6	3.0
Reasoning No. Correct	95	23.3	4.4	8.0	30.0
Object Rotation No. Correct	95	66.0	18.5	16.0	90.0
Orientation No. Correct	95	15.7	6.6	0.0	24.0
Maze No. Correct	95	17.9	6.0	6.0	60.0
Map No. Correct	95	13.5	4.9	0.0	20.0
Nelson Denny Score	94	135.0	24.1	73.0	169.0
Criteria					
Hit Rate--Execise A	95	3.7	1.9	0.0	8.0
Hit Rate--Execise B	95	6.8	1.7	2.0	10.0
Hit Rate--Execise C	95	5.5	2.0	1.0	10.0
Opening Time--Exercise A	94	16.1	2.7	10.0	23.0
Opening Time--Exercise B	94	11.7	2.8	5.1	19.0
Opening Time--Exercise C	92	16.2	2.6	10.0	22.0
Tracking Root Mean Square Error	90	1.3	0.5	0.6	4.0
UCOFT Composite Score	95	-50.0	43.5	-183.0	41.0

[a]Times are in hundredths of seconds
bTimes are in seconds

Table 4

Factor Loadings for UCOFT Scores from Principal Components Analysis with Varimax Rotation.

Dependent Variables	Factor 1
Hits	
Exercise A[a]	-.50
Exercise B	-.35
Exercise C	-.60
Opening Times	
Exercise A	.66
Exercise B	.57
Exercise C	.72
Tracking Root Mean Square Error	.53

[a] Exercise A = Own stationary tank, moving target
B = Own tank moving, stationary target
C = Own tank degraded and stationary, moving target

Table 5

Results of Stepwise Multiple Regression of UCOFT Composite Score on the Individual Predictor Variables

Variables in Equation[a]	*B*		*F*[b]
Choice Reaction Time: Movement Time Mean	-1.36		17.24
Tracking 1	-1.49		19.84
Number Memory: pooled operations time mean	1.27		10.20
Number Memory: final response time mean	-1.02		7.03
Target Identification. movement time mean	1.39		15.97
Orientation number correct	.98		8.95
Number Memory: input response time mean	-1.56		18.62
R		.76	
R^2		.58	
Adjusted R^2		.55	
Overall Model F		17.26	

[a]Stepwise analysis required $p<.05$ to stay in equation.
[b]All *F* reported have $p<.01$.

weight, indicating the largest relative effect on the criterion, and Orientation Number Correct has the smallest effect of the included variables. The other variables in the model are Tracking 1, Target Identification Movement Time Mean, Choice Reaction Time movement Time Mean, Number Memory Pooled Operations Time Mean, and Number Memory Final Response Time Mean. Note that Nelson-Denny Score, used as a measure of general ability, did not enter into the equation. In comparison to $\underline{R}$, the correlation of Nelson-Denny with Composite Score is only approximately .20. Thus, general ability can explain only 4% of the criterion variance -- variance which is not unique from that explained by the regression model.

This reduced set of seven independent variables represents a subset of variables particularly related to UCOFT Composite Score. These variables were then entered into a discriminant analysis to attempt to classify subjects according to membership in successful (upper 95%) versus unsuccessful (lower 5%) Composite Score performance groups. The cutoff score defining the two groups was -132. Table 6 contains the classification table obtained from the analysis. The three out of five in the unsuccessful group who were correctly classified were the three lowest scoring subjects. Although this represents 40% error, the two incorrectly assigned subjects (i.e., false positives) were borderline cases falling very close to the cutoff score, with nearly equal probability of assignment to either group according to the discriminant analysis. False negatives (i.e., those incorrectly assigned to the unsuccessful group) represent a small percentage (4.5%) of the successful group. In all, approximately 94% of the subjects were correctly classified. Because the unsuccessful group is extremely small ($\underline{n}$=5), we repeated the discriminant analysis after forming two equal groups ($\underline{n}$=32) representing the top and bottom thirds of the distribution. As seen in Table 7, 80% of the subjects were correctly classified. In this instance only 28% of the lower group were false positives while 13% of the upper group were false negatives

Table 6

Classification Summary from Discriminant Analysis of UCOFT Composite Score Using Reduced Set of Independent Variables.

Actual	Predicted		
	Unsuccessful	Successful	Total
Unsuccessful	3	2	5
Successful	4	86	90

Percent of Cases Correctly Classified = 94%

Given that both Exercises A and C employed moving targets while Exercise B used stationary targets and that gunnery performance with stationary targets has been difficult to predict in the past (e.g., Eaton, Bessemer, & Kristiansen, 1979), we also ran separate stepwise regressions of composites (including Tracking RMS error) over Exercise A with C and for B alone. These regressions are summarized in Tables 8 and 9. The multiple correlation obtained for A and C ($\underline{R}$ = .73; shrunken $\underline{R}$=.71) is almost as large as for all three exercises totaled. The model contains six variables, including two of the spatial tests. The results of the regression on Exercise B are less impressive. Five variables entered the equation and the model can account for only 34% of variance in the criterion. No spatial tests entered the equation. The three regression models (for all exercises, A with C alone, and B alone) had three variables in common: Choice Reaction Time Movement Time Mean, Tracking 1, and Target Identification Movement Time Mean.

Table 7

Classification Table From Discriminant Analysis of UCOFT Composite Score for Lower and Upper Thirds of the Distribution Using Reduced Set of Independent Variables

Actual	Predicted	
	Lower Third	Upper Third
Lower third	23	9
Upper third	4	28
Percent of Cases Correctly Classified = 80%		

For reference only, results from additional stepwise regressions of the individual criterion variables Total Hits, Total Opening Times, Speed Accuracy combination, Tracking RMS Error, and Speed Accuracy by exercise are presented in Tables A-1 to A-7 in the Appendix. Multiple $\underline{R}$s for these criteria range from .43 to .73. Any interpretation of these findings is limited because of intercorrelation of the variables and inflated Type 1 error. In addition, for comparison, zero-order correlations of Nelson-Denny Score with various dependent measures are given in Table A-8 in the Appendix. Table A-9 presents zero-order correlations of the other predictor variables and criterion scores.

Using Project A CV data analysis as a model, we decided to form the predictor variables into composites and repeat the regression and discriminant analyses with Composite Score as the criterion. We ran a principal components factor analysis with varimax rotation and compared

Table 8

Results of Stepwise Multiple Regression of UCOFT Composite Score for Exercises A and C Combined on Individual Predictor Variables

Variables in Equation[a]	B		F[b]
Choice Reaction Time: movement time mean	-.93		11.61
Tracking 1	-1.58		32.87
Cannon Shoot: percent hits	-.58		5.00
Target Identification: movement time mean	.63		5.25
Reasoning: number correct	.87		9.64
Map: number correct	.69		5.85
R		.73	
R^2		.53	
Adjusted R^2		.50	
Overall Model F		16.59	

[a]Stepwise analysis required $p < .05$ to stay in equation.
[b]All F reported have $p < .05$.

Table 9

Results of Stepwise Multiple Regression of UCOFT Composite Score for Exercise B Only on Individual Predictor Variables

Variables in Equation[a]	B		F[b]
Choice Reaction Time: percent correct	.35		3.99
Choice Reaction Time: movement time mean	-.49		7.17
Tracking 1	-.54		9.65
Target Identification: movement time mean	.56		9.72
Number Memory: input response time mean	-.52		8.54
R		.59	
R^2		.34	
Adjusted R^2		.31	
Overall Model F		9.37	

[a]Stepwise analysis required $p < .05$ to stay in equation.
[b]All F reported have $p < .05$.

the factor structure obtained with this small AOB sample to that obtained with the large CV sample (as reported in Campbell (1986)). Both analyses resulted in 6-factor solutions, but the factors were only moderately different. Table 10 presents the factor loading matrix on which we based our predictor composites. Note that the loadings were not completely clean: double and even triple loadings occur for several variables using a cutoff loading of .35. Scores were unit-weighted positively or negatively according to the sign of the loading and assigned to the one factor on which each score loaded highest. Table 11 compares the makeup of our composites to those of Project A. The table along with analyses discussed below show that there are no really substantial differences between the composites based on this small sample of officers and the presumably more stable composites based on the large CV enlisted sample.

Table 10

Factor Loading Matrix Defining AOB Predictor Composites Based on Principal Components Analysis with Varimax Rotation

	Spatial Abilities	Tracking/ Psychomotor	Perceptual Speed and Accuracy	Numerical Operations	Reaction Time	Movement Time
Reasoning Test	$\boxed{.65}$	-.03	.29	-.06	-.24	.12
Object Rotation	$\boxed{.59}$	-.13	-.08	-.08	.08	-.13
Orientation Test	$\boxed{.75}$	-.15	.12	-.06	-.20	-.08
Maze Test	.22	$\boxed{-.35}$	.13	.04	-.21	.04
Map Test	$\boxed{.45}$	-.30	-.10	-.23	-.12	.01
Simple Reaction Time						
Percent Correct	.15	.09	.19	.08	$\boxed{-.38}$	-.02
Decision Time Mean	-.02	.19	.03	.31	$\boxed{.56}$	.12
Choice Reaction Time						
Percent Time Mean	.28	.21	.21	.07	-.13	.26
Decision Time Mean	-.02	.25	.28	.39	$\boxed{.54}$	.15
Memory						
Percent Correct	.13	-.05	.06	.07	$\boxed{-.56}$	.25
Decision Time Mean	.22	-.12	$\boxed{.40}$	.35	.23	.39
Tracking 1	-.23	$\boxed{.86}$	.10	.14	-.02	-.06
Perceptual Speed						
Percent Correct	.19	-.10	$\boxed{.57}$	-.04	-.06	-.13
Decision Time Mean	-.28	-.07	$\boxed{.62}$	.21	.06	.17
Tracking 2	-.25	$\boxed{.75}$	.05	.11	.08	.01
Number Memory						
Percent Correct	.28	-.10	$\boxed{.63}$	-.09	-.16	.03
Final Response Time Mean	-.19	.07	.01	$\boxed{.53}$	.18	.52
Pooled Operations Mean	-.08	-.14	.09	$\boxed{.73}$	.06	.09
Input Response Time Mean	-.15	.13	.04	$\boxed{.70}$	-.05	-.09
Cannon Shoot						
Mean Absolute Time Discrepancy	-.06	$\boxed{.40}$	-.11	-.05	.13	.05
Target Identification						
Percent Correct	.05	-.01	$\boxed{.46}$	.06	-.06	.03
Decision Time Mean	-.38	.17	$\boxed{.56}$	.20	.20	-.02
Target Shoot						
Mean Time To Fire	-.45	$\boxed{.46}$	.17	.14	.01	.22
Mean Log (Distance + 1)	.16	$\boxed{.62}$	-.13	-.16	.05	-.01
Pooled Mean Movement Time	-.11	.07	-.02	-.04	-.09	$\boxed{.74}$

Table 11

Comparison of Composites for Present Research (AOB) and Project A Concurrent Validation (CV)

Composite Name	Armor Officer Basic (AOB)	Composite Name	Concurrent Validation (CV)
Spatial Ability[a]	Reasoning Test (+) Object Rotation Test (+) Orientation Test (+) Map Test (+)	Spatial	Reasoning Test (+) Orientation Test (+) Map Test (+) Object Rotation (+) Maze Test (+)
Psychomotor Ability	Tracking 1 - Mean Log (Distance + 1) (+) Tracking 2 - Mean Log (Distance + 1) (+) Target Shoot - Mean Log Distance + 1) (+) Target Shoot - Mean Time to Fire (+) Cannon shoot - Absolute Time Discrepancy (+) Maze Test (-)	Psychomotor	Target Tracking 1-Mean Log (Distance + 1) (+) Target Tracking 2-Mean Log (Distance + 1) (+) Target Shoot-Mean Log (Distance + 1) (+) Target Shoot-Mean Time to Fire (+) Cannon Shoot-Absolute Time Descrepancy (+) Pooled Mean Movement Time (+)
Accuracy Perceptual Speed	Perceptual Speed & Accuracy-Percent Correct (+) Perceptual Speed & Accuracy-Decision Time Mean (+) Target Identification-Percent Correct (+) Target Identification-Decision Time Mean (+) Short Term Memory-Decision Time Mean (+) Number Memory-Percent Correct (+)	Perceptual Speed Perceptual Accuray	Perceptual Speed & Accuracy-Decision Time Mean (+) Target Identification-Decision Time Mean (+) Short Term Memory-Decision Time Mean (+) Perceptual Speed & Accuracy-Percent Correct (+) Target Identification-Percent Correct (+) Short Term Memory-Percent Correct (+)
Numerical Operations	Number Memory-Pooled Operation Time Mean (+) Number Memory-Input Time Mean (+) Number Memory-Final Response Time Mean (+)	Numerical Speed & Accuracy	Number Memory-Percent Correct (-) Number Memory-Pooled Operation Time Mean (+) Number Memory-Input Time Mean (+) Number Memory-Final Response Time Mean (+)
Reaction Time[b]	Simple Reaction Time-Percent Correct (-) Simple Reaction Time-Decision Time Mean (+) Choice Reaction Time-Decision Time Mean (+) Memory-Percent Correct (-)	Simple Reaction Speed Simple Reaction Accuracy	Simple Reaction Time-Decision Time Mean (+) Choice Reaction Time-Decision Time Mean (+) Simple Reaction Time-Percent Correct (+) Choice Reaction Tiem-Percent Correct (+)
Movement Time	Pooled Mean Movement Time		

[a]CV included one additional spatial test not used in current research

[b]CV broke this into 2 composites - Simple Reaction Speed and Simple Reaction Accuracy

Stepwise regression of Composite Score on the predictor composites resulted in a multiple $R = .58$ (shrunken $R=.57$). Thus, only 34% of the variance in the criterion can be explained by the predictor composites. The regression model includes only the Spatial Abilities and Tracking/Psychomotor Abilities composites, with the former having the greater relative effect on Composite Score. Table 12 summarizes these results. Reformulation of the composites according to the Project A CV configuration resulted in nearly identical results, as is seen in Table 13. Discriminant analysis with the two AOB predictor composites as independent variables resulted in fewer false negatives, but twice as many false positives, as there are using the individual predictor variables. That is, there is better classification using the individual variables. The classification table from the analysis is given in Table 14. Results from the discriminant analysis using the upper and lower thirds as criterion groups are presented in Table 15. Here there were fewer false positives and more false negatives than with use of the individual variables.

Table 12

Results of Stepwise Multiple Regression of UCOFT Composite Score on AOB Predictor Composites

Variables in Equation[a]		B	F[b]
Spatial Abilities		.55	17.39
Tracking/Psychomotor Abilities		-.28	10.31
R	.58		
R^2	.34		
Adjusted R^2	.33		
Overall Model F	23.40		

[a] Stepwise analysis required $p<.05$ to stay in equation.
[b] All F reported have $p<.01$.

Table 13

Results of Stepwise Multiple Regression of UCOFT Composite Score on Project A CV Predictor Composite

Variables in Equation[a]	B	F[b]
Spatial Abilities	.50	19.16
Psychomotor Abilities	-.34	7.61
R	.57	
R^2	.33	
Adjusted R^2	.32	
Overall Model F	22.17	

[a] Stepwise analysis required $p<.05$ to stay in equation.
[b] All F reported have $p<.01$.

Table 14

Classification Summary from Discriminant Analysis of UCOFT Composite Score Using Spatial and Psychomotor Predictor Composites

Actual	Predicted		
	Unsuccessful	Successful	Total
Unsuccessful	1	4	5
Successful	1	89	90
Percent of Cases Correctly Classified = 95%			

Table 15

Classification Summary From Discriminant Analysis of UCOFT Composite Score for Lower and Upper Thirds of the Distribution Using Spatial Psychomotor Predictor Composites

Actual	Predicted	
	Lower Third	Upper Third
Lower third	25	7
Upper third	6	26
Percent of Cases Correctly Classified = 80%		

DISCUSSION

In the present research, there were many variables of interest and only a small sample of subjects. This situation limited both the analytical approach taken and the interpretation of the findings. As it is, because of the exploratory nature of this research, more analyses were performed than typically would be acceptable. Given the complexity of the data, we attempted to simplify matters by first creating and concentrating on a straightforward criterion composite that represented overall UCOFT performance. Regression analyses using individual predictor scores (as well as composites of these scores) as independent variables indicate that the test battery has substantial validity for predicting our criterion.

We looked at the predictors from two perspectives -- as individual variables and combined into composites -- to determine if one approach had more merit than the other in predicting criterion performance. We found a higher level of validity was achieved using individual predictor scores rather than composites. The regression model consisting of four computerized tests and one paper-and-pencil test from our psychomotor perceptual battery has excellent predictive validity ($R = .73$). The Number Memory test contributes three variables to the regression model: Input Response Time, Final Response Time, and Pooled Operations Time. These scores, to an extent, may represent some general ability (related more to quantitative than verbal ability, however) and cognitive speed. The Choice Reaction Time and Target Identification scores in the model were for movement time means, emphasizing motor efficiency. An oversimplification of these results suggests that perhaps the better gunners think quick, act fast, and remain steady on target. Although interpretation of why these particular variables have substantial effect on the criterion is not that simple, the fact remains that the tests can be used to predict criterion performance validly. In contrast, Nelson-Denny score, as a measure of general ability, demonstrates little predictive validity ($\underline{r}=.20$) for gun-

nery performance as measured here, even though Nelson-Denny Scores show more variability than we expected in this sample. That is, the general ability test does not tap into the kinds of abilities needed for the criterion performance of interest here but psychomotor and predictor tests do. Of course, it is essential to emphasize that these results are based on a small sample and are not likely to hold on cross-validation. Nonetheless, given the magnitude of multiple $\underline{R}$, even with changes in the model (e.g., inclusion of different variables) and considerable shrinkage, in cross-validation we would expect to obtain moderate (or better) validity.

The results of the regression analysis involving the predictor composites have the advantage of somewhat easier interpretation: Spatial and tracking psychomotor abilities significantly impact UCOFT performance. The simplicity of this interpretation provides face validity as well as criterion validity. On the other hand, using predictor composites resulted in lower criterion validity. Although the difference in the percent of variance accounted for by the two models is 26%, the 32% explained by the model based on composite scores is still a substantial amount. In addition to the fact that there is greater error, based on our results, another disadvantage to using the composites regression model for the future is the requirement of administration of all five of the paper-and-pencil spatial tests and three of the computerized tests. (Note: if CV composites were used, an additional five computer tests would be required). In comparison, provided that the results reported here are replicated with other samples, fewer tests are needed when using the individual variables model. Given that these findings may not be replicated, however, any future research in this area should include all variables.

When the variables from the two regression models were entered into discriminant analyses, both provided fairly accurate classifications of subjects, with individual variables giving more accurate assignment of unsuccessful subjects than do composites. Our categorization of subjects as successful and unsuccessful was arbitrary. A five percent failure cutoff may be too high. Our purpose for performing the analysis was to determine to what extent classification based on some fairly reasonable criterion was possible. In this case, there is a high level of accuracy (94%), with most errors due to marginal cases--those close to the cutoff score. Using the top and bottom thirds for groups, there is an 80% accuracy level.

Exercises A and C were similar in that both used moving targets, even though Exercise C involved the degraded mode. On the average, subjects were more accurate on Exercise B: It is easier to hit a stationary target. Performance on Exercise B composite score, however, is not predicted as well as that on Exercises A and C combined using our test battery. Spatial abilities effect Exercises A and C, but do not impact on B. The multiple $\underline{R}$ for Exercise B is substantial ($\underline{R}$ = .59), but some of this is due to prediction of the Tracking RMS component of this score. If we consider only hits and opening times for Exercise B, our predictors can only account for 19% of the variance in performance. The predictor battery used here does not really tap into the abilities needed for gunnery

performance with stationary targets. Because average performance under this condition is better, however, it is probably not as important that we be able to predict it. The fact that prediction is poorer for this type of criterion also suggests that any future validations with these or any other predictors carefully consider this before using gunnery performance with stationary targets as the performance measure.

CONCLUSIONS

The Chief of Armor has developed Armor officer assessment procedures which evaluate the professional development of the Armor officer and delineate personnel management and professional decisions. The purpose of the assessment is to provide guidance to the Armor officer, thereby better enabling him to choose his career pattern. Included in the assessment plan is a proposed pre-accession screen which would select officers with the physical and psychomotor attributes necessary to operate and maintain the highly technological equipment being developed in Armor. Armor has proposed expanding the physical and visual requirements of accessed officers and the development of a hand eye coordination test. The present effort was the first step in the development of an Armor Officer pre-accession screen.

The results of this research are highly encouraging. The Project A predictor test battery has excellent criterion validity for gunnery performance, here measured by overall performance on the UCOFT. The results have clearly demonstrated that more than general ability tests are necessary to predict this criterion. Further, the results have shown that the Project A paper-and-pencil and computer tests of psychomotor, perceptual, and spatial abilities which were administered appear to be excellent candidates for the Armor officer pre-accession screen. Given our results, additional research is needed to determine how well these findings hold on crossvalidation, and to determine appropriate standards for UCOFT performance and cutoff scores for predictor tests.

REFERENCES

Campbell, J. P. (1986). Validation analysis for new predictors. (Working Paper RS-WP-86-09). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Eaton, N. K., Bessemer, D. W., & Kristiansen, D. M. (1979). Tank crew position assignment. (ARI Technical Report 391). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A077 841)

Eaton, N. K., Goer, M. H., Harris, J. H., & Zook, L. M. (October 1984). Improving the selection, classification, and utilization of Army enlisted personnel: Annual Report, 1984 Fiscal Year. (ARI Technical Report 660). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 994)

Graham, S. E. (1986). The Unit Conduct of Fire Trainer (UCOFT) as a medium for assessing gunner proficiency: Test reliability and validity. (ARI Research Report 1422). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A169 196)

Peterson, N. G. (Ed.). (1987). Development and field test of the Trial Battery for Project A. (ARI Technical Report 739). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A184 575)

Rapkoch, J. M., & Robinson, F. D. (1986, June). Concept evaluation program of gunnery training devices. (Final Report). Fort Knox, KY: U.S. Army Armor & Engineer Board.

Scribner, B. L., Smith, D. A., & Phillips, R. L. (1986). Are smart tankers better? AFQT and military productivity. Armed Forces & Society, 12, 193-206.

The Division 86 Tank Platoon. (1986, October). (Field Circular 17-15). Ft. Knox, KY: U.S. Army Armor School.

APPENDIX A

Table A-1

Results of Stepwise Multiple Regression of UCOFT Hits Score Over All Exercises on Individual Predictor Variables

Variables in Equation[a]	B		F[b]
Tracking 2	-.85		16.58
Number Memory: Input response time mean	-.61		8.71
R		.52	
R^2		.27	
Overall Model F		16.96	

[a] Stepwise analysis required $p<.05$ to stay in equation.
[b] All F reported have $p<.01$.

Table A-2

Results of Stepwise Multiple Regression of UCOFT Opening Times Over All Exercises on Individual Predictor Variables

Variables in Equation[a]	B		F[b]
Choice Reaction Time: movement time mean	.66		9.48
Tracking 1	.87		14.89
Map: number correct	-.59		6.87
R		.56	
R^2		.32	
Overall Model F		14.19	

[a] Stepwise analysis required $p<.05$ to stay in equation.
[b] All F reported have $p<$

Table A-3

Results of Stepwise Multiple Regression of UCOFT Speed/Accuracy Score Over All Exercises on Individual Predictor Variables

Variables in Equation[a]	B	F[b]
Choice Reaction Time: movement time mean	-1.40	21.32
Tracking 1	-1.53	26.26
Target Identification: movement time mean	.78	6.73
Map: number correct	.81	7.30
Number Memory: input response time mean	-.86	8.26
R	.73	
R^2	.53	
Overall Model F	20.13	

[a]Stepwise analysis required $p<.05$ to stay in equation.
[b]All F reported have $p<.01$.

Table A-4

Results of Stepwise Multiple Regression of UCOFT Tracking (Root Mean Square Error) on Individual Predictor Variables

Variables in Equation[a]	B	F[b]
Cannon Shoot: absolute time discrepancy mean	-.25	7.59
Target Shoot: mean log (distance +1) error	.26	8.44
Orientation: number correct	-.39	19.39
Perceptual Speed: movement time mean	-.31	12.75
R	.56	
R^2	.32	
Overall Model F	10.41	

[a]Stepwise analysis required $p<.05$ to stay in equation.
[b]All F reported have $p<.01$.

Table A-5

Results of Stepwise Multiple Regression of UCOFT Speed/Accuracy Score for Exercise A Only on Individual Predictor Variables

Variables in Equation[a]	*B*	*F*[b]
Choice Reaction Time: movement time mean	-.36	10.08
Tracking 1	-.94	60.28
Cannon Shoot: percent hits	-.43	13.24
Reasoning: number correct	.39	11.00
R	.73	
R^2	.54	
Overall Model *F*	26.09	

[a]Stepwise analysis required $p<.05$ to stay in equation.
[b]All *F* reported have $p<.01$.

Table A-6

Results of Stepwise Multiple Regression of UCOFT Speed/Accuracy Score for Exercise B Only on Individual Predictor Variables

Variables in Equation[a]	*B*	*F*[b]
Simple Reaction Time: movement time mean	-.38	7.15
Number Memory: input response time mean	-.51	12.88
R	.43	
R^2	.19	
Overall Model F	10.47	

[a]Stepwise analysis required $p<.05$ to stay in equation.
[b]All *F* reported have $p<.01$.

Table A-7

Results of Stepwise Multiple Regression of UCOFT Speed/Accuracy Score for Exercise C Only on Individual Predictor Variables

Variables in Equation[a]	B		F^b
Choice Reaction Time: movement time mean	-.42		9.15
Tracking 1	-.44		8.75
Reasoning: number correct	.38		6.17
Map: number correct	.34		4.66
R		.60	
R^2		.36	
Overall Model F		12.46	

[a]Stepwise analysis required $p<.05$ to stay in equation.
[b]All F reported have $p \leq .01$.

Table A-8

Zero-order Correlations Between Nelson-Denny Test and UCOFT Scores

	Exercises			
Scores	Overall	1	2	3
Hits	.17	.21*	-.01	.19
Opening Times	-.19	-.16	-.16	-.18
Tracking	-.19	-	-	-
Speed/Accuracy	.23*	.24*	.09	.22*
Total Composite	.26*	.25*	.19	.25*

* $p<.05$

Table A-9
Zero-order Correlations Between Predictor Variables and UCOFT Criterion Scores.

Predictors	Criteria				
	Hits	Opening Times	Speed/ Accuracy	Tracking RMS Error	Composite Score
Simple Reaction Time					
Percent Correct	-.04	.02	-.03	.02	-.03
Decision Time Mean	.01	.15	-.09	.04	-.09
Movement Time Mean	-.15	.30**	-.28**	-.02	-.24*
Choice Reaction Time					
Percent Correct	.22*	-.15	.23*	-.17	.24
Decision Time Mean	-.10	.33**	-.27**	.11	-.26**
Movement Time Mean	-.26*	.29**	-.34***	-.08	-.28**
Short Term Memory					
Percent Correct	.04	-.10	.09	-.07	.09
Decision Time Mean	.11	.07	.02	-.07	.04
Movement Time Mean	-.19	.04	-.14	-.07	-.11
Tracking 1					
Mean Log (Dist + 1) Error	-.44****	.45****	-.54****	.28**	-.55****
Perceptual Speed and Accuracy					
Percent Correct	.08	-.11	.12	.01	.10
Decision Time Mean	.02	.02	.00	-.05	.01
Movement Time Mean	.03	-.06	.06	-.29**	.12
Tracking 2					
Mean Log (Dist + 1) Error	-.45****	.39****	-.52****	.26*	-.51****
Number Memory					
Percent Correct	.13	-.21*	.21*	-.03	.19
Final Response Time Mean	-.12	.27**	-.25*	.00	-.22*
Pooled Operations Time Mean	-.04	.02	-.04	.04	-.04
Input Response Time Mean	-.37***	.31**	-.42****	.24*	-.43****
Cannon Shoot					
Percent Correct	-.05	-.19	.09	.14	.05
Absolute Time Discrepancy Mean	-.09	.10	-.12	-.15	-.07
Mean Log (Dist + 1) Error	.03	.15	-.08	-.17	-.03
Target Identification					
Percent Correct	.14	-.05	.11	-.14	.13
Decision Time Mean	-.23*	.26*	-.30**	.08	-.29**
Movement Time Mean	.05	-.02	.04	-.20	.08
Target Shoot					
Percent Correct	.19	-.20	.24*	-.28**	.28**
Mean Time To Fire	-.12	.31**	-.27**	.16	-.27**
Mean Log (Dist + 1) Error	-.23*	.15	-.23*	.21	-.25*
Reasoning No. Correct	.33***	-.27**	.37***	-.24*	.38****
Object Rotation No. Correct	.35***	-.24*	.36***	-.23*	.37***
Orientation No. Correct	.23*	-.35***	.36***	-.34***	.39****
Maze No. Correct	.26*	-.17	.26*	-.19	.27**
Map No. Correct	.30**	-.35***	.40****	-.28**	.42****

* $p < .05$
** $p < .01$
*** $p < .001$
**** $p < .0001$